Oh, dear: double-check your optical testing equipment!
by Bob Buchheim

You all probably remember the sick feeling in your stomach when you first heard about the fabrication flaw in the mirror of the Hubble Space Telescope. The "root cause" was an unfortunate goof-up in optical testing. The specifications for the mirror were so tight that Perkin-Elmer had to design and build a super-precise interferometer to do the testing of the big mirror. Unfortunately, nobody realized that the newly-built interferometer had unrecognized spherical aberration within it. Hence, the big mirror was polished to a precisely spherically-aberrated figure.

Sad story, but happily a combination of clever image processing and (later) installation of a corrective-optics assembly has enabled the Hubble to deliver an astounding array of scientific results and gorgeous images.

I innocently assumed that this would be the first and last such mistake. But an article in the April 2007 *Publications of the Astronomical Society of the Pacific* had a title that caught my curiosity: "Restoration of Images of Comet 9P/Tempel 1 Taken with the Deep Impact High Resolution Instrument" (by D. Lindler, et al). Remember that *Deep Impact* sent an impactor into the comet to blast out a sample of the material beneath the surface – an exciting and very successful mission.

Why was image restoration needed? Because the imager was accidentally placed 6.4 mm behind the focal surface of the telescope. How did that happen? Quoting from the PASP article: "The spacing was incorrectly set during ground testing based on optical tests performed at a cold operating temperature. The cause of the problem was traced to a cryo-flat used during ground calibration that developed optical power at cold temperatures." Oh, dear!

I don't remember this getting any publicity during the mission. I mention it here because some of you are involved in spacecraft design and fabrication, and aerospace product development. So am I. And I sometimes get frustrated with how long it takes my engineers to conduct a seemingly straightforward test or experiment. Many times, the explanation for the larger-than-hoped-for cost and schedule hangs on the need to confirm that the instrumentation is calibrated for the test conditions being used, confirm that the experiment will deliver the information that is desired, and confirm that the data is an accurate representation of "truth" (i.e. the data isn't corrupted by unforeseen offsets or gain errors).

I can't say that I'm always graceful about accepting such explanations. But events like the Deep Impact telescope deserve to be widely known in the aerospace community, to remind us (engineers, technicians, and managers) that things may not be what they seem to be, and that they can go horribly wrong without any alarm bells being rung. It is very important to take the time to ask, "Why do I believe that this test, fabrication method, or integration check is adequate?" and "How do we know that the test equipment and test method are able to deliver what we're expecting of them, in the conditions that we're using them?" When you're asking and answering these questions, demand that your team apply both historical knowledge of past events (like *Deep Impact*) and fertile imaginations. There may be only one way for things to "go right", but there is a near- infinite number of ways that things can "go wrong".

By the way, the OCA Library receives the PASP each month, and it is available for you to check out and peruse. See Karen for the current year's issues.